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METHODS FOR THE PREDICTION OF SOLID WASTE CHARACTERISTICS

Final Report

February 1969

Contract No. PH 86-67-Neg 98

For

BUREAU OF SOLID WASTE MANAGEMENT
222 East Central Parkway
Cincinnati, Ohio 45202

URS SYSTEMS CORPORATION

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The basic concept of the solid waste prediction model developed in this project is: The waste generated by a community is derived primarily from the goods and materials consumed by the community, therefore waste quantities and characteristics can be estimated from information concerning the consumption habits of the community and the manner in which is uses and consumes the material obtained. The study consists primarily of determining the availability of usable information and developing a preliminary prediction model for residential household solid wastes. The model's performance was tested by comparing its predictions for a given locality with the results of an actual study of solid waste generation in that locality. The areas studied were in Jefferson County, Kentucky.

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by

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Section 1
INTRODUCTION

The design, implementation, and operation of efficient and economical solid waste collection, handling, transport, and disposal systems requires accurate information on the quantities and characteristics of the solid waste. This information is needed for the present as well as throughout the entire useful lifetime of the waste management system. The overall objective of the work of the study reported herein is to develop methods that can be applied to real (or hypothetical) cities, counties, and/or regions to estimate the quantity and character of the solid wastes generated at present and at various times in the future.

The work was planned to be implemented in two phases:

1. Preparation of preliminary design of the prediction model and determination of its feasibility.

2. Completion of the development of the model; preparation of the associated computer programs; assembly of appropriate data banks; and conduct of test runs for specific areas.

This report describes the work undertaken in the first phase and includes the results and conclusions of the first phase. Also included are recommendations regarding the concepts and approaches for the work to be performed in the second phase.

Within the scope as specified in the contract for Phase 1, URS Research Company undertook to:

A. Develop specifications for and design the basic waste prediction model.

   (1) Investigate and establish output information format pertinent to the anticipated use of the data, placing particular importance upon the degree of detail in description of materials, location of waste, and the time at which waste is produced.

   (2) Identify and investigate sources of information on input commodities and activity characteristics and define type and quality of information available.

(3) Compare output specifications with input data availability and develop a compatible model.

B. Collect, develop, and formulate selected standard data, descriptors, and functions for input commodities and activities. This would involve an analytical study of materials, commodities, community activities, and waste production. Although much information is available, it shall have to be modified to the format needed in the model. Various sources will have to be evaluated relative to prediction of the character of commodities in the future. One of the items of information anticipated to be somewhat difficult to obtain is the "residence time" data. In the initial study, only a selected spectrum of input commodities and activities will be evaluated.

C. Test the model manually in a relatively small community. This task will be used to evaluate the general performance of the model. Manual computation will be used to avoid costly programming and computer time while the model is in a preliminary stage of development. A small community or a segment of a community will be selected, and information on the quantity of input materials will be obtained. The waste characteristics will be predicted and compared to data collected at disposal or other sites. The selection of the sample will be made on the basis of providing a significant sample of the most important prediction parameters.

D. Evaluate test results and evaluate the practicality of the model, including an evaluation of the possible accuracy and precision of the system and the delineation of limitations to the system.

Section 2
SUMMARY

The basic concept of the solid waste prediction model developed in this project is:

> The waste generated by a community is derived primarily from the goods and materials consumed by the community, therefore waste quantities and characteristics can be estimated from information concerning the consumption habits of the community and the manner in which it uses and consumes the material obtained.

Such an approach facilitates the prediction of future waste characteristics because of the widespread availability of information concerning the production, use, and composition of goods and materials in the future.

The study consisted primarily of determining the availability of usable information and developing a preliminary prediction model for residential household solid wastes. This model was restricted to the prediction of present-day, short-residence-time wastes. Its performance was tested by comparing its predictions for a given locality with the results of an actual study of solid waste generation in that locality. The areas studied were in Jefferson County, Kentucky. Pertinent demographic data were collected and the solid waste quantities of various materials estimated by manual application of the prediction method. The results compared favorably with the measured values.

It is recommended that additional work be performed in order to:

- Complete the development of the residential household prediction model; modify it to include institutional and commercial activities; computerize the model; and run a test case.
- Perform a preliminary development and feasibility test of similar methods for predicting industrial, agricultural, and other selected wastes.

TABLE 1. QUANTITIES OF SELECTED WASTE MATERIALS GENERATED IN TEST COMMUNITY (AREAS OF JEFFERSON COUNTY, KENTUCKY)

(lbs/household/week)

	MEASURED BY UNIV. OF LOUISVILLE STUDY		ESTIMATED BY URS PROTOTYPE MODEL
	low	high	
paper	24.9	37.8	23.43
glass	3.8	6.7	2.54
metal	3.9	6.0	4.23

Section 3
DISCUSSION AND GENERAL APPROACH

An intimate knowledge of the composition of the waste is needed as a basis for the design of waste management systems and for the planning of research and development for solid waste handling and treatment processes. The technical feasibility of incineration, composting, and other processes; the operational practicality of collection, segregation, and secondary-material recovery systems; and the economic feasibility of all aspects of waste handling require detailed information regarding the source, quantity, and quality of all waste materials. In order to effectively perform such studies, the changes in characteristics of waste materials (resulting from population growth, land use modification, and techrological changes in material properties and industrial processes) must be predicted for several decades.

The usual method of obtaining data on waste characteristics and quantity is by physically inventorying the materials delivered to the disposal site. While such an approach provides information which can be useful in formulating immediate solutions to current problems,* its use as the primary basis for defining and solving long-range problems is suspect for the following reasons:

- Inventorying present and past wastes cannot serve as a basis for predicting future waste characteristics or quantity since it does not account for any of the technical, social, economic, or other factors which influence waste generation.
- The difficulty of segregating and identifying waste components (after they have been stored, compacted, transported, and repeatedly handled) severely reduces the accuracy of any quantitative description.
- Studies conducted at the disposal site generally do not provide adequate information concerning the sources of waste.
- The discard rate for many types of waste is too discontinuous, relative to time, to allow conventional surveys to obtain sufficiently representative samples.

---

* Data derived from conventional waste measurement and analyses have been valuable to the present study in that they provide baseline waste generation information and serve to indicate where better definition is needed.

This study is concerned with a waste prediction technique which is based on the following hypothesis:

> The wastes discarded by a community derive primarily from the materials purchased, consumed, and used by that community (i.e., "inputs"); therefore, one can predict the amount and nature of these waste "outputs" by identifying what goods and materials constitute the community's inputs and by knowing how the community acts upon these inputs.

It is implicit, then, that studying the characteristics of commodities, materials, and products and their "consumption" by society will reveal information about the resulting waste. It should be noted that the time required for a given material to pass through the community is an important consideration and varies widely for different materials (or products) according to the uses to which they are put. Some input materials, such as foods, are received, distributed, consumed, and become waste in a matter of hours or days. Other products, such as those used in construction, may be resident in the community for half a century or longer before they become waste.

In a discrete community, the input materials may be acted on by the community in the following primary ways. The community:

1. consumes them, eventually converting all the input materials to waste. For example, a case of canned vegetables (consisting of solid food, liquid food, metal cans, and a fiberboard box) entering a community will be converted entirely to waste within a few weeks.*

2. processes them for consumption elsewhere, with only a fraction becoming waste in the community. For example, most of the steel and plastics shipped to a manufacturing plant will leave the area, their only trace in the community being the small amount of production scrap and the few units sold in the area.

3. generates materials, in the sense that agricultural crops, vegetation, and livestock are grown, and resources are obtained from mines and wells. In most cases, the materials generated within the area are consumed outside the area, although waste materials will remain in the area.

Table 2 is a partial listing of the various community activities related to consumption, processing, and generation. Obviously, not all activities

---

* For purposes of predicting solid wastes, only the packaging materials are of interest.

Table 2. SIGNIFICANT COMMUNITY ACTIVITY CLASSIFICATIONS[a]

Consumption activities:

a. Residential households (single- and multiple-family dwellings)

b. Financial and business establishments (including government activities)

c. Institutions

d. Restaurants

e. Utilities (including water and waste treatment)

f. Transportation

Processing activities:

a. Industrial:

- Food processing
- Manufacturing of durable and nondurable goods
- Chemical manufacturing, processing, refining

b. Construction

c. Commercial (retail and wholesale marketing)

Generation activities:

a. Agriculture

b. Mining (including petroleum)

c. Commercial fishing

d. Demolition

e. Miscellaneous (e.g., street sweeping, gardening)

---

[a] These classifications relate closely to those of the Bureau of Budget's Standard Industrial Classification,[1] and to the system proposed by the Urban Renewal Administration and the Bureau of Public Roads for land use classification,[2] thus facilitating the use of the vast amount of data available from the federal government.

are exclusively in one category or another. For instance, all processing and generating activities are also consumers of some input materials, but to a lesser extent.

The estimation of the solid waste materials produced by any given community, through the use of the concepts proposed herein, involves primarily:

- Compiling an inventory of all waste producing activities in the community.
- Compiling (a) standard information on the materials consumed per unit size per unit time by each type of activity, and (b) information regarding which of these materials becomes solid waste.
- Determining the rate of solid-waste production from the above information.

Information on the rate of material consumption (and therefore, waste generation) by each type of activity is derived from many sources and is based largely on descriptions of the material input-output characteristics of the processes utilized by each activity. Although the actual computations and data bank formulations will vary somewhat, depending on the type of activity being considered, the basic computational approach shown in Fig. 1 is applicable. The basic data banks (rectangles on the diagram) of the model shown in Fig. 1 can be described as follows:

Description of Community, a data bank which provides an inventory of each type of activity in the study community; their number, size, and location.* This is actually an inventory of waste sources.

Description of Standard Activity, a data bank that indicates for each type of activity the amount of waste items** and materials that are produced per unit time per unit size of activity. This data bank would be of a general nature and would apply to the study of any area of the country.

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* Location refers here to census tract, enumeration district, county, urban area, or some other segment of the area being studied.

** In the terminology used herein, "waste item" refers to a recognizable, discrete object made up of one or more materials. For example, a discarded television set or sofa is a "waste item." A "waste material" is a more specific classification of waste content, e.g., glass, copper, paper, wood, textiles, etc.

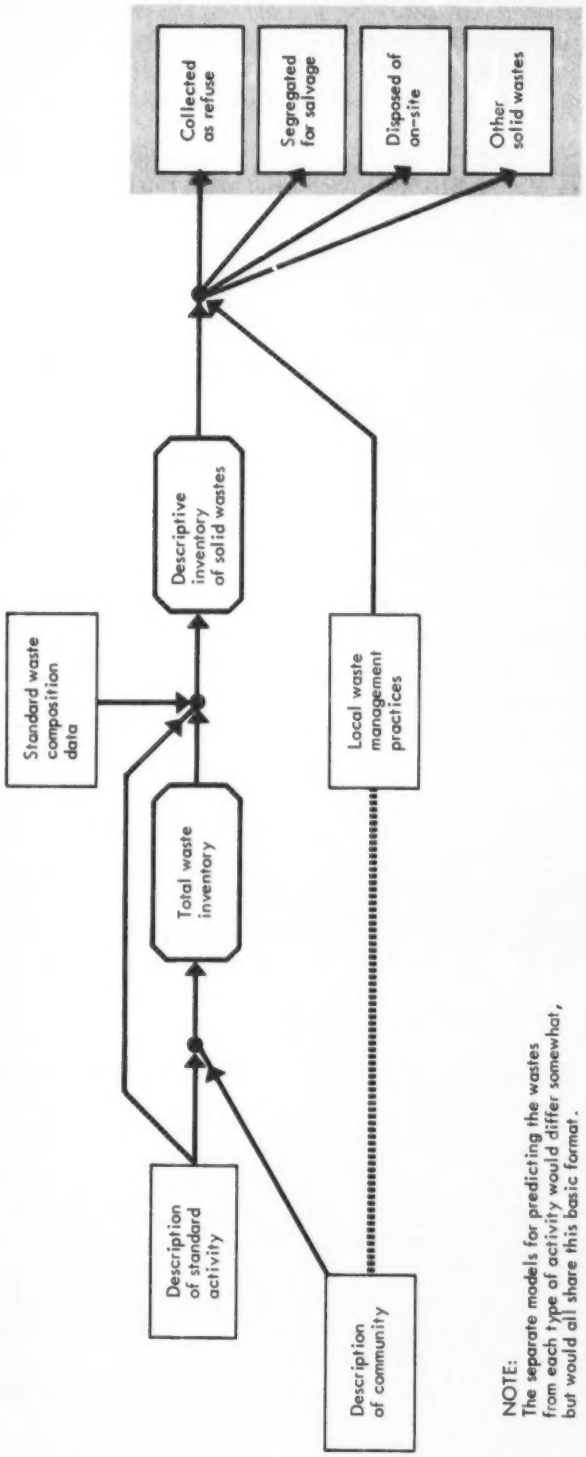
Collected as refuse
Segregated for salvage
Disposed of on-site
Other solid wastes
Descriptive inventory of solid wastes
Standard waste composition data
Local waste management practices
Total waste inventory
Description of standard activity
Description of community
NOTE:
The separate models for predicting the wastes from each type of activity would differ somewhat, but would all share this basic format.

Fig. 1. Solid Waste Prediction Model - Conceptual Diagram

Standard Waste Composition Data, a standard data bank that provides the information needed to convert a unit of input item into quantities of waste materials which it will yield. For example, N pounds of coffee would be converted to X pounds of granular solids, Y pounds of metal (from the can), Z pounds of plastic (from the lid), etc.

Local Waste Management Practices, a data bank which provides information on the manner in which specific wastes from specific sources are ultimately disposed of by the community (i.e., whether they are collected as refuse, segregated for salvage, disposed of on-site, or otherwise eliminated). This information is specific for each community and reflects both the habits of the residents and the legal restrictions on disposal practice.

The intermediate compilations (shown as irregular octagons) resulting from the various computations are:

Total Waste Inventory, which lists the quantity of all waste items produced in each location within the study area. It is derived from the first two data banks.

Descriptive Inventory of Solid Wastes, which lists the quantity of each waste item and waste material that is likely to end up as a "solid waste." Those materials that become airborne or waterborne wastes are eliminated from consideration. This information is derived by using additional process data from the Activity Description and/or from Waste Composition Data to develop the waste material inventory.

The final output of the model is a series of compilations (shown as shaded blocks) including:

Inventory of Wastes Collected as Refuse, which lists the quantities of waste items and materials that are normally collected for disposal.

Inventory of Wastes Segregated for Salvage, which lists the quantities of waste items and materials that are segregated (by the activity) and either recycled within the process or collected separately for reuse, resource recovery, or salvage.

Inventory of Wastes Disposed of On-Site, which lists the quantities of waste items and materials that are disposed of by the activity itself. This would include, for example, materials burned in an incinerator, ground in a garbage grinder, buried, or otherwise processed for disposal.

Inventory of Other Solid Wastes, which includes those waste items and materials not elsewhere accounted for.

As indicated, the wastes are tabulated in two ways: by the amount of each item (e.g., pounds of tin cans, washing machines, etc.) and by the amount of constituent material (e.g., pounds of paper, ferrous metal, plastic). This appears to meet the requirements of the initial uses of the model. It is anticipated, however, that it will be useful to introduce further calculations (not shown in Fig. 1) that will convert the basic waste inventories so that they reflect other waste characteristics, such as calorific value, biochemical degradability, chemical composition, bulk density, real density, unit size, etc.

Figure 1 is a generalized overview of the basic waste prediction model required for each activity. A more specific version, applicable to the residential household, is shown in Fig. 2. The corresponding models applicable to other types of activities would differ somewhat in detail from this but would share the basic format shown in Fig. 1.

The model shown in Fig. 2 not only redefines some data banks in relation to the household activity function, but also incorporates consideration of two important aspects of the ultimate computational procedure:

- The wastes from short-resident-time (SRT) items are predicted separately from wastes from long-residence-time (LRT) items.*
- Data banks required for predicting waste quantities and characteristics at selected times in the future are included.

In this study, no specific useful-life duration was established to differentiate between SRT and LRT items. However, items that are "consumed" within a year or less are generally considered to be SRT items. Even without a rigidly established criterion, little difficulty was experienced in assigning items to one category or the other.

Separating the prediction processes for SRT and LRT wastes is necessary because:

---

* LRT items are those which tend to remain in use (or at least in "storage") in the normal household for a relatively long period of time. Examples would include furnishings, appliances, books, tools, and the like. Examples of SRT items would include food, periodicals, most clothing, and disposable paper and plastic goods.

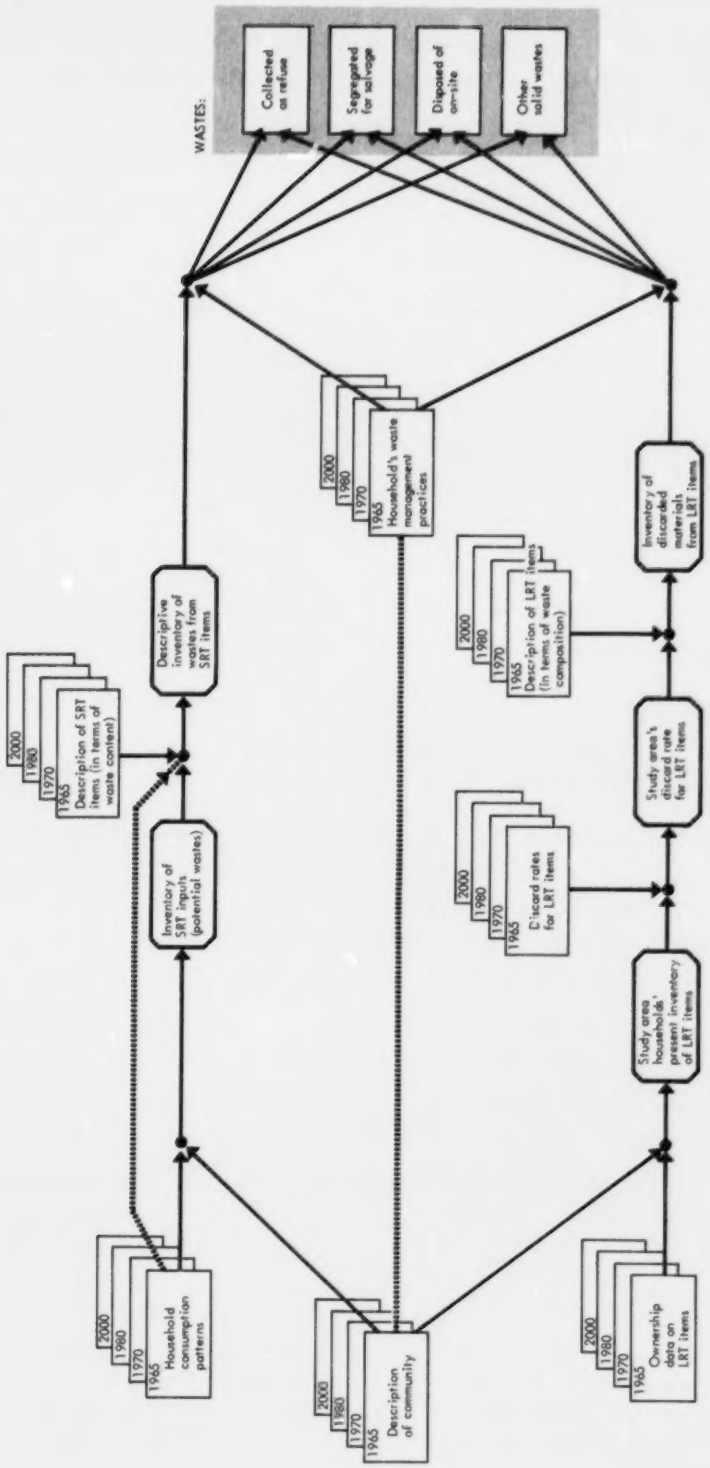
WASTES:
Collected as refuse
Segregated for salvage
Disposed of on-site
Other solid wastes
Household's waste management practices
Inventory of discarded materials from LRT items
Description of LRT items (in terms of waste composition)
Descriptive inventory of wastes from SRT items
Description of SRT items (in terms of waste content)
Study area's discard rate for LRT items
Discard rates for LRT items
Inventory of SRT inputs (potential wastes)
Study area households' present inventory of LRT items
Household consumption patterns
Description of community
Ownership data on LRT items
2000
1980
1970
1965

Fig. 2. Household Waste Prediction Model - Expanded to Account for Long Residence-Time and Short Residence-Time Items Separately

- Household inventories of LRT items tend to increase; therefore, a purchase of such an item does not necessarily result in the immediate discard of a like item, as distinguished from SRT items, which are used essentially immediately and become waste in the same general period in which they are procured.

- Because the material characteristics of many LRT items change with changes in technology, and since those being discarded today were manufactured 5 to 15 years ago, special consideration must be given to the material characteristics of the item.

The means of predicting both LRT and SRT wastes are discussed in detail in Section 4.

An important use of the prediction model is related to the estimation of waste characteristics in the future. In order to use the model for such a purpose requires predictions and forecasts of future changes in:

- Descriptions of communities
- Household consumption patterns (and descriptions of standard activities)
- Composition of SRT and LRT items
- Household waste management practices
- Ownership data on LRT items
- Discard rate data

Generally the most valid predictions of changes in materials, products, and technology will be those made by persons having the best knowledge of the specific technologies and industries involved. Similarly, the most important predictions of the growth and change of a given community are those generated by the responsible authorities within the community. Therefore, the method shown (that of having essentially separate data banks for each predictive year) was chosen partly because it provides a means of incorporating independent predictions from different sources.* At present, it is planned to use 1965 as the base year with 1970, 1980, and 2000 as projection years. In applying the model, only one year

* The problem remains, of course, of assuring that independent predictions are reasonably compatible. This would be done at the time the predictions are evaluated and the data banks prepared.

would be considered at a time. Although forecasts are available for many specific items of information (e.g., estimates of their anticipated growth made by communities), it may be possible and desirable to develop specialized models (and computer programs) to systematically forecast the growth of selected activities. The specific means of generating these forecasts is not within the scope of this study.

Figure 3 is a detailed diagram of the household waste prediction model that has been developed during this phase of the study. It follows the general format discussed above, but employs several minor modifications. For instance, the figure illustrates the methods used for developing the data banks that describe the product cost and composition. This prototype model concentrates on SRT items and considers but one time period (i.e., it cannot make forecasts of future wastes). A detailed description of the model shown in Fig. 3 is presented in Section 5.

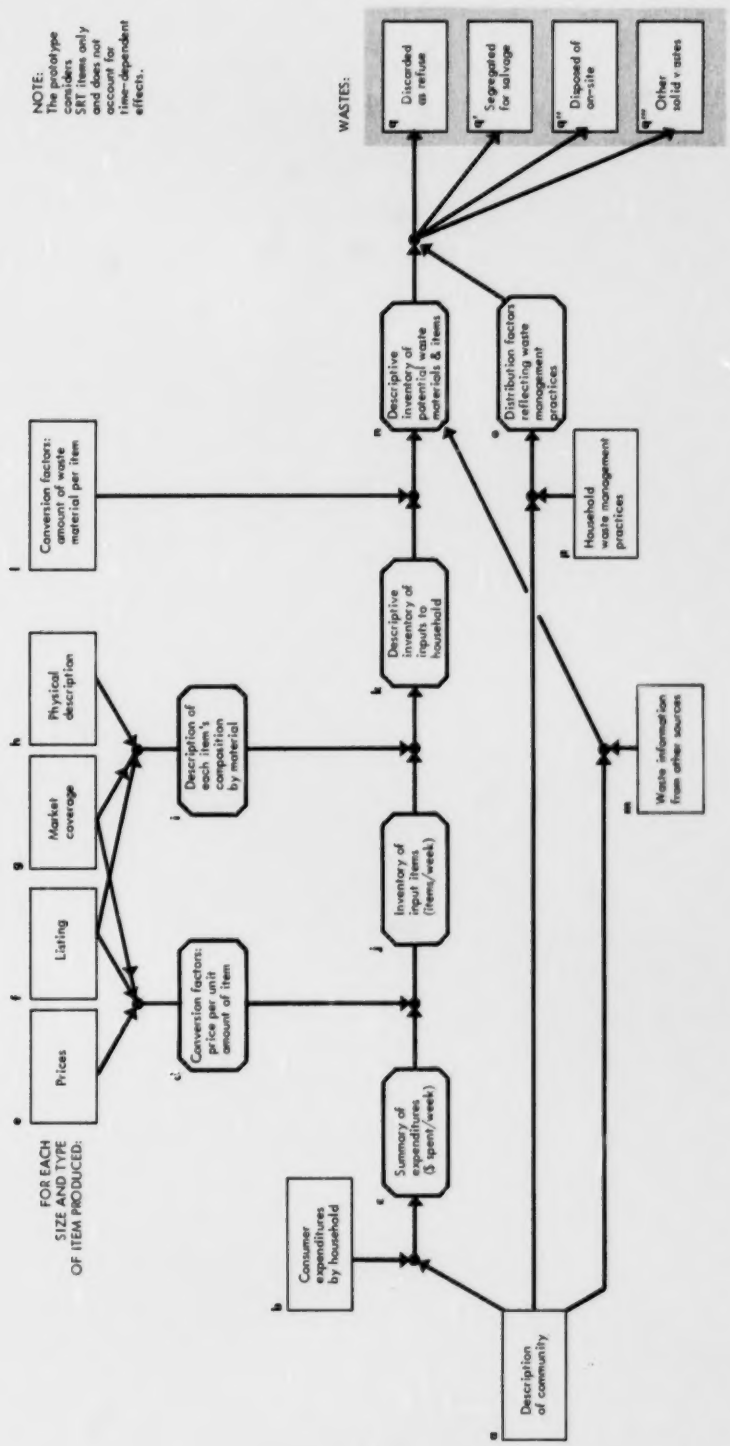
NOTE:
The prototype considers SRT items only and does not account for time-dependent effects.
WASTES:
q' Discarded as refuse
q'' Segregated for salvage
q''' Disposed of on-site
q'''' Other solid wastes
Descriptive inventory of potential waste materials & items
Distribution factors reflecting waste management practices
Conversion factors: amount of waste material per item
Descriptive inventory of inputs to household
Household waste management practices
Description of each item's composition by material
Physical description
Market coverage
Listing
Prices
Inventory of input items (items/week)
Waste information from other sources
Conversion factors: price per unit amount of item
Summary of expenditures ($ spent/week)
Consumer expenditures by household
Description of community
FOR EACH SIZE AND TYPE OF ITEM PRODUCED:

Fig. 3. Household Waste Prediction Model

Section 4
HOUSEHOLD-WASTE PREDICTION TECHNIQUE

The household-waste problem was chosen as the subject for this preliminary development and feasibility study because it embodies, in many ways, the most complex prediction problems. In addition, the collection, transport, and disposal of household waste represent the most costly and widespread waste management problems, and their effective solution is dependent on useful waste characteristic data.

The basic computational model developed for household waste prediction is shown in Fig. 2. Although the model is large in that it handles a sizable amount of numerical data concerning expenditure rates, consumer item descriptions, use patterns, and disposal practices, it is simple in that only basic arithmetic functions are used in manipulating the data.

The general aspects of the computational model are discussed in this section, while the specific application of the model is described in Section 5.

Bases for Household Waste Model

The fundamental element of the model in Fig. 2 is the data bank entitled "Description of the Community." The number of persons living in each area of the community is, of course, the community characteristic most pertinent to the household-waste problem. This information is readily available from the Bureau of Census. Additional descriptors, such as number of families and income distribution among families, provide information pertinent to the consumption habits of the residential sector.

The "Description of the Standard Activity" is a data bank that indicates the quantitative input-output characteristics of the activities – in this case, the residential household. During the initial phases of the study, several approaches to determining the "input" materials to a community's households were investigated, including consideration of the means of inventorying the shipments into the community, the shipments to wholesalers and distributors,

etc. However, from a review of available information, it became obvious that studies of consumer buying habits would be the most practical sources of data. Of the various studies of this type, the most applicable one encountered is a report entitled Expenditure Patterns of the American Family.[3] The report was prepared by the National Industrial Conference Board in 1965 under the sponsorship of LIFE Magazine. (It will be referred to herein as "the LIFE study.") It was based upon statistical data collected as part of an unusually comprehensive series of surveys of consumer behavior conducted by the Bureau of Labor Statistics, U.S. Department of Labor. It contains a vast quantity of data on the rate at which households spend money on about 700 different goods and services. The important feature of this study is the information on the manner in which each of these expenditures varies relative to factors such as family size, family income, geographical region, etc.*

One limitation of the LIFE study, relative to its use for waste prediction, is that the results are reported in dollars expended. Consequently, a considerable portion of the research effort was directed toward converting the reported expenditure rates into material input rates. The LIFE study states how many dollars are spent (per household per week) on common consumer items, such as canned coffee. Consequently, it was necessary to obtain sufficient additional information to convert this dollar expenditure figure to pounds of steel can, pounds of plastic lid, and pounds of spent coffee grounds (per household per week), since these are the potential solid wastes.

Other major tasks involved deciding whether or not these potential wastes actually become waste, how this occurs, and the form of the wastes. These factors depend upon how the household processes the "input" material. For most items, information concerning use patterns came from a general knowledge of household operations, rather than from formal data sources. The details on the means of obtaining and manipulating the various types of information concerning each input in order to obtain final waste-generation predictions are discussed in the following paragraphs.

---

* A more complete listing of factors used for the various tabulations of expenditures is given in Tables 3 and 4, pages 24, 25 and 26.

Prediction of LRT Items

A major problem, as previously indicated, arises from the necessity of predicting the disposal of items that have a relatively long useful life. In actuality, today's household waste consists of three major fractions:

- SRT items, including their packages and containers, that have been purchased recently.
- The containers and packaging materials which accompany the LRT items that have been purchased recently.
- LRT items purchased in the past.

Although the LIFE study data provide information that can be used as a basis for the predictions of waste from the first two items, they are not useful for the prediction of the third, since the purchase of a new LRT item is not automatically accompanied by the discard of an older one.

The following characteristics, common to many LRT items, make prediction of their waste characteristics difficult:

1. Their discard rate is difficult to estimate because of the tendency to increase the per capita resident inventory of many items.
2. Many items discarded by one population group are reused by other population groups in different locations before finally being discarded as refuse.
3. Technological changes in manufacturing processes, product design, and materials have resulted in changes in the composition of many items.

The first of these characteristics is related to a number of factors, including:

- A general increase in disposable income
- A continuing reduction in the base price of many LRT items
- The occurrence of buying trends which are based upon status and affluence motivations
- The low salvage value of outmoded but still operable items.

Television sets are a good example of this tendency. When television was first introduced, ownership was quite limited, whereas now virtually all families

own a set, and many own two or more. Television ownership has risen from 20 percent of all families in 1950 to over 93 percent at present[4]. Many other items (e.g., radios, small appliances, boats, etc.) also show an increased per capita inventory. The tendency of many families to maintain more than one residence (e.g., vacation homes) also complicates the prediction procedure.

The fact that many LRT items can be put to use by someone other than the original purchaser complicates waste prediction in that it interferes with determining the location at which the item will ultimately be discarded as waste. This problem also interferes with estimating the useful life of many items. To date, very little information has been found on the useful life of durable goods.

The third problem, that of introducing composition changes into the program, is not overwhelming. Actually, most of the significant changes appear to have occurred rather recently, and their general characteristics can be inferred from trade literature. The problem is largely related to obtaining sufficiently accurate "average" composition information for the various items.

Specific methods for predicting the quantities and characteristics of yesterday's LRT waste have not been developed to date. However, the major problems have been identified and several concepts have been briefly explored. The computational procedure shown in Fig. 2 is believed to be conceptually correct. It shows the use of the data bank "Ownership Data for LRT Items" to indicate the quantities of durable goods that are used or stored in typical households of various economic levels. This type of information is available from the Bureau of Labor Statistics, Bureau of Census, and various nongovernmental sources, although it must be evaluated and coordinated before use.

The data bank "Discard Rates for LRT Items" will be more difficult to develop. The desired output, "number of each type of items of X years average age discarded per household per unit time," can probably be derived for many items from production and ownership data. However, the derivation will be somewhat laborious and time consuming, unless a computer program is developed to assimilate the available data.

The data bank "Description of LRT Items" will provide information on the composition of the discarded LRT items. The format of the information is

dependent on the output of the "discard rate" data and the assumptions concerning the composition of LRT items of various sizes, types, ages, and brands. This information will be costly to collect if the accuracy requirements are demanding.

As previously indicated, no computational procedure for prediction of LRT waste was developed and used as part of this study. Its development will be an important initial aspect of our subsequent work.

Quantities of solid waste derived from SRT household items have been estimated by means of the computational approach shown in Fig. 3. Section 5 includes a detailed description of the development and use of the model.

Section 5
HOUSEHOLD WASTE PREDICTION MODEL

As previously indicated, the computational procedure used in this study for predicting household waste is shown schematically in Fig. 3. The following discussion examines various portions of the prediction model and explains their content, function and relationships.

To some extent, the description relates more directly to the methods used for the manually performed case study, rather than those which will be developed for eventual computer solution. Figure 4 diagrams that segment of the overall model (Fig. 3) which pertains to the development of the inventory of input items to the household. It deals with all inputs other than LRT consumer items.

Prediction of Input Items

Block c, the summary of expenditures, is the result of the initial computation. It indicates the amount of money all households in a study area will spend collectively on each of a large number of consumer items. The expenditures are expressed in terms of "dollars spent per unit time" and are tabulated on an item-by-item basis (e.g., expenditure rates for bread, soap, and floor wax are expressed separately). This expenditure summary is based upon information regarding the way an individual household of a particular type spends money on various items (consumer expenditures by household, block b) combined with information on how many households of each type are located within the study area (descriptive information on households in study area, block a).

The consumer expenditure data (block b) were obtained primarily from the LIFE study[3] described previously. Data are expressed in terms of "dollars spent per household per unit time" and are tabulated on an item-by-item basis. The data in the LIFE study are presented in the form of a large matrix, the row headings being items, the columns being household characteristics. The body of the matrix itself consists of the expenditure rates each type of household

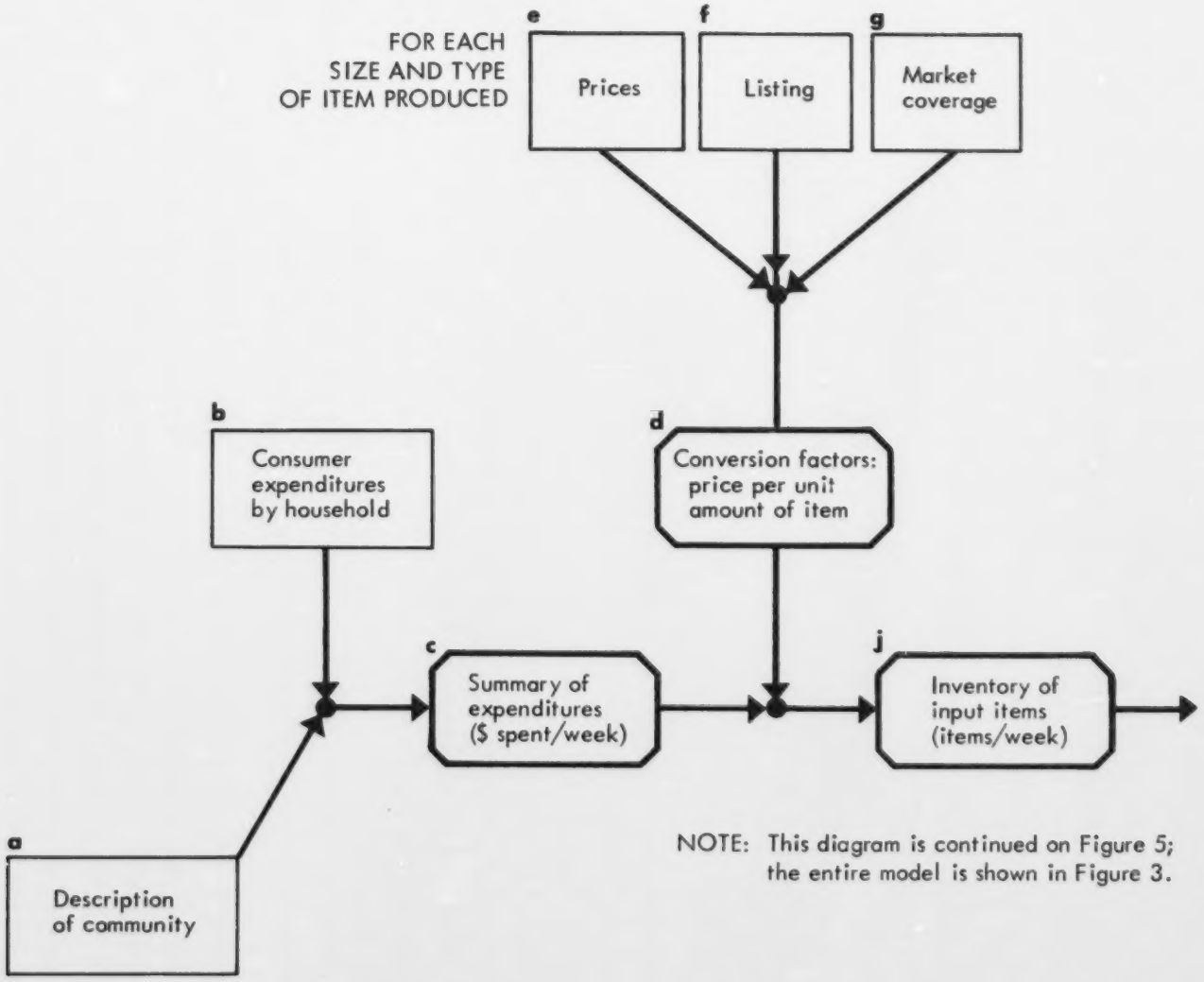

Fig. 4. Segment of Household Waste Prediction Model

will have for each particular item listed (there are tens of thousands of such rates listed, all given to the nearest cent per week). Tables 3 and 4 are lists of the major groupings of row and column headings, respectively, in the LIFE study. In summary, there is a wide variety of information available, but generally only those data relatable to income and section of the country are directly applicable.

The community descriptions (block a) provide information on the demographic and socio-economic nature of the study area. The following factors were found to provide the most useful information on the people and the activities in the study area:

- Population
- Population density
- Average size of household
- Distribution of income
- Number, size, and type of establishments:
  - wholesale trade
  - retail trade
  - selected services
  - manufacturers
  - mineral industries
  - agriculture

For any given study area, the most desirable sources of such information might differ somewhat but would generally include the following:

- U.S. Department of Commerce (especially the Bureau of Census and the Business Defense Services Administration)
- U.S. Department of Labor (Bureau of Labor Statistics)
- State departments of commerce
- Local chambers of commerce
- Various state and local agencies concerned with commercial and industrial development

The inventory of input items (block j) is computed by multiplying the expenditure per unit time for each item (from summary of expenditure, block c)

TABLE 3. LIST OF MAJOR EXPENDITURE CATEGORIES

	Number of items* listed
Food, beverages and tobacco	
- cereals and bakery products	23
- meats, poultry and fish	18
- milk, cream and cheese	11
- fruits and vegetables	47
- other foods	56
- alcoholic beverages	5
- tobacco	4
Housing and household operations	
- shelter and other real estate	17
- household operations	22
- household supplies	20
Housefurnishing and equipment	
- household textiles	14
- furniture	11
- floor coverings	8
- major appliances	18
- small appliances	4
- housewares	12
- miscellaneous items	11
Clothing and accessories	
- clothing (aggregated by sex and age)	142
- clothing materials	1
- clothing upkeep	3
Transportation	
- automobile purchase	2
- auto operating expenses	10
- auto insurance	5
- repairs and parts	1
- other auto expenses	1
- local transportation	1
- intercity transportation	6
- other transportation expenses	5

* Some of these "items" are actually aggregations of related individual items. For example, the following aggregation is listed as a single "item" of men's clothing: Suits, sport-coats, and trousers.

Table 3 (Cont.)

	Number of items* listed
Medical and personal care	
- group plans and insurance	3
- in hospital care	3
- professional services	3
- drugs and medicine	6
- other medical care	1
- personal care services	5
- personal care supplies	14
Recreation and equipment	
- TV, radios and musical instruments	10
- spectator admissions	4
- participant sports	3
- club dues and memberships	1
- hobbies	5
- toys and play equipment	7
- recreation out of home city	1
- other recreation	1
All other goods and services	
- reading	6
- education	4
- other current expenditures	4
- additional disbursements	7
Total number of items and aggregations of items listed	= 566

TABLE 4. LIST OF HOUSEHOLD CHARACTERISTICS

	Number of Categories Listed
Age of head of household	6
Stage in life cycle (indicates ages of children)	6
Family size	5
Family income	6
Earner composition (identifies bread-winners)	4
Occupation of head of household	6
Geographical region	4
Race	2
Market location (proximity to metropolitan area)	5
Home tenure (owned or rented)	2
Education of head of household	5
Total number of categories listed =	51

by the unit cost of the corresponding item (price/amount conversion factors, block d). Thus, block j gives the number of units of each item entering the study area per unit time. The amounts are expressed in terms of whatever units of measure are most appropriate for the particular item (e.g., dozens of eggs, loaves of bread, pounds of coffee, pairs of shoes, etc.).

The price/amount conversion factor (block d) is derived in a subroutine that establishes the average price per unit amount, taking into account the different sizes and types of units that are commonly produced and marketed. This subroutine is also used to estimate the "average composite package unit," which is used in a subsequent computation. The data for these subroutines come from a wide variety of sources, including surveys. Care must be taken to assure that costs are taken for a common year; in addition, regional variations may have some effecton on cost.

The preceding discussion has been limited to that portion of the model shown in Fig. 4 and is applicable to the following:

- SRT consumer items
- The containers and packaging materials which accompany SRT items
- The containers and packaging materials which accompany LRT items

Prediction of Potential Wastes

The following paragraphs are concerned with the means of using the input inventory to develop waste predictions. The discussion is keyed to Fig. 5.

Block i represents a tabulation of information which describes each item in terms of its material composition (i.e., pounds of glass, steel, plastic, paper, etc.). It is at this point in the model that each item consumption rate would be defined in more detail. For example, W pounds of coffee per week would be defined as X pounds of granular solids, Y pounds of tinplated steel cans, Z pounds of plastic lids, etc. These values will be the "average" for a composite unit size package and will be based on the market coverage (i.e., distribution) of sizes and types of packages. For example, 50 pounds of coffee cannot be interpreted as 50 cans of 1-pound size. Rather, it will consist of some mix of 1/2-, 1-, 2-, and 3-pound metal cans, plus some mix of special paper

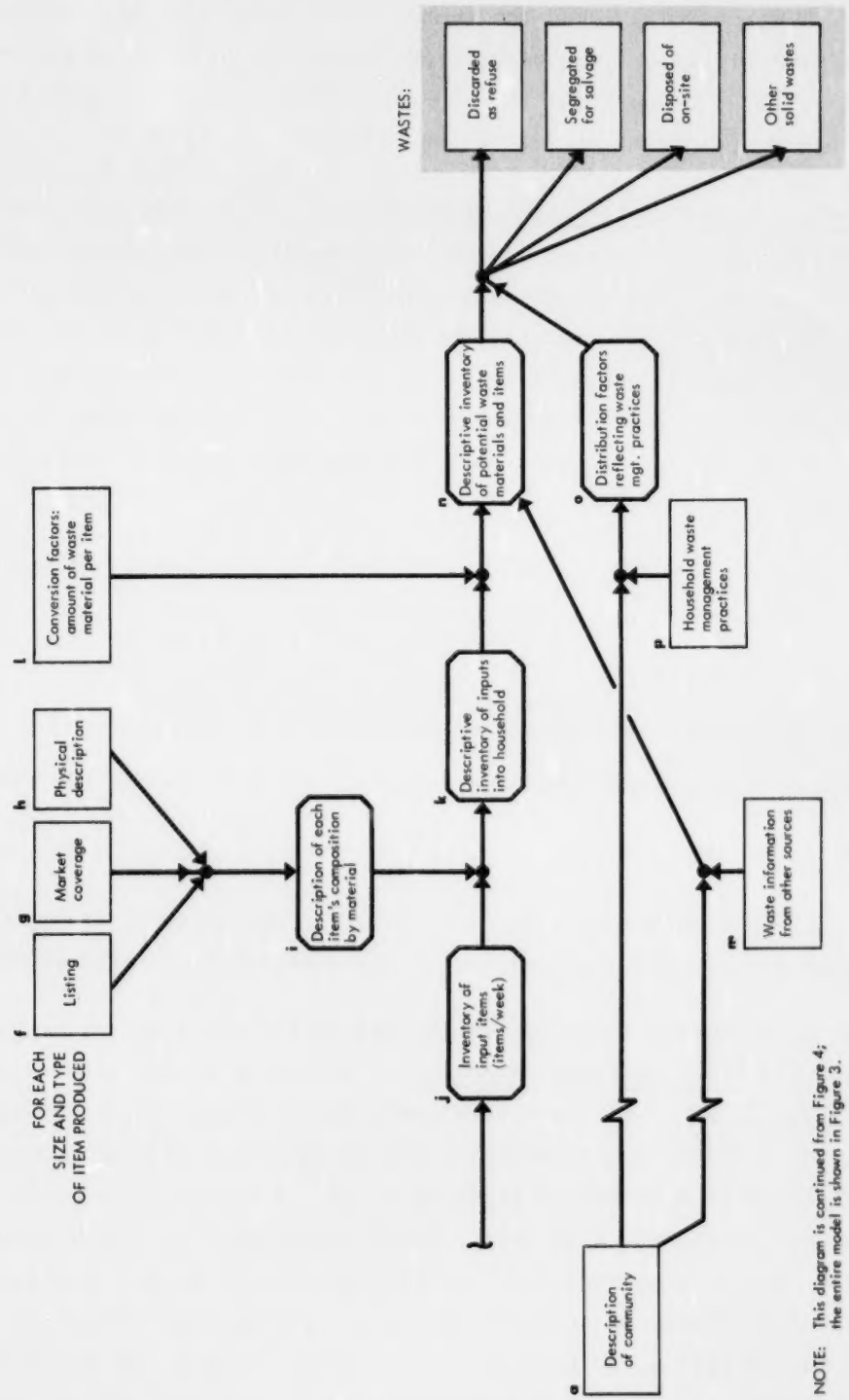

Fig. 5. Segment of Household Waste Prediction Model

bags. Since each of these alternative containers will affect the household waste differently, it was necessary to devise a simple method to account for them. The method used here was to merely construct a hypothetical "pound of coffee," m percent of which comes in one size and type of container, n percent of which comes in another size and type, and so on. An alternative method would be to consider every size and type available on the market as a separate item. However, the problems of data storage (and availability) rule out this approach immediately. In this study, descriptive information was obtained primarily by collecting, disassembling, and weighing a multitude of items and their associated containers and packaging. The marketing information of blocks f, g, and h provides a basis for assigning weighting factors which reflect the relative importance of various sizes and types of items available (i.e., considering again the example of ground coffee, marketing information[8] indicates that major emphasis should be placed upon the 1-pound and 2-pound cans and only minor emphasis on bags).

Combining the input item inventory (block j) with the description of each item (block i) yields a descriptive inventory (block k) of the material which enters the household. This inventory indicates, in separate tabulations, both materials and items which enter the household.

The waste/item conversion factor (block l) is introduced to indicate the primary fate of materials that enter the household. The various alternatives are:

- Solid waste
- Airborne wastes (e.g., aerosol-type hair spray, air deodorants, etc.)
- Liquid, i.e., sanitary waste (e.g., cleansers, food, tissue, etc.)
- Distributed within residence so as to be "lost" (e.g., floor wax)
- Distributed outside residence so as to be "lost" (e.g., fertilizer, pet food, etc.)
- Prolonged "storage"

Those items not entering the solid waste stream must be carried in the original inventory because of the need to include their containers as solid waste. It is anticipated that in the computerized model this function will be included

in block h, the data bank which gives the composition and content of items. Applying the waste/item conversion factors of block l to the inputs (i.e., combining blocks k and l) yields the descriptive inventory of potential waste items and materials (block n).*

Block m has been included to allow the direct introduction of data on those wastes which are best estimated outside the model. Examples of wastes handled this way include:

- Newspapers and periodicals
- Mail
- Grocery bags and cartons used to transport groceries
- Leaves, grass, and garden cuttings
- Floor sweepings

These wastes are considered separately because their quantities are not dependent upon the household's expenditure on a particular consumer item.** Newspapers and mail are estimated on the basis of information from local publishers and postal authorities; grocery sacks on the basis of national production figures; leaves, grass, garden cuttings, and sweepings on the basis of information concerning population density, income, and the degree to which the study area is built-up. To date, we have not been able to develop sufficient information to allow us to make quantitative predictions of how the generation of these materials will vary with given demographic factors, although the experimental studies of waste composition conducted and sponsored by the Bureau of Solid Waste Management should be very useful.

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* Note that the waste materials listed in this inventory are still keyed to the parent item from which they originated.

** The amount of newspaper entering a household does seem to depend upon the family's expenditure on newspapers. Actually, the number of copies may correlate well with expenditure, but the fact that the size of newspaper of a given price varies widely precludes estimating the weight of paper consumed. For example, the subscription price for a small-town newspaper may equal that of the New York Times. The former constitutes a few pages; the latter, a few pounds.

Prediction of Solid Waste Quantity

Block o consists of a series of distribution factors that indicate the ultimate fate of solid wastes and reflect the manner in which households typically handle waste materials. These factors indicate the portion of each spent item that will be disposed of via each of the various disposal alternatives. For example, it might state that, from an input of 1 pound of ground coffee, 20 percent of the spent grounds would enter the sanitary sewer (via the sink, presumably), 80 percent of the grounds would be disposed of via the garbage can and 100 percent of both the metal can and its plastic lid would leave the garbage can. The influence of other local practices, such as whether back-yard incineration is permitted, would also be incorporated in this computation. These distribution factors of block o are based upon:

- Information concerning the waste management practices of various typical types of households (block p)
- Information giving the number of households of each such type located in the study area, as given by the community descriptors (block a).*

Applying these distribution factors to the inventory of potential wastes (i.e., combining blocks o and n) yields a series of new tabulations (blocks q, q', q'', q'''), which describe the amount and nature of waste material disposed of via the available disposal alternatives. This final set of tabulations is the end product of the prediction model. Their format is merely a listing of the quantities of wastes generated in the particular study area.

* It should be noted that, at the present state of the art, only the most rudimentary, qualitative information is available concerning the relationship between measurable socio-economic/demographic factors (such as block a) and the waste management practices of the corresponding households (block p). For the purpose of this study, the information of block q was developed primarily on the basis of intuitive judgement.

Section 6
DESIGN OF MODEL AS USED FOR TEST CASE

The primary objective of this study was to develop selected parts of the waste prediction concept into an operable technique and to test its feasibility by applying it to a real community. In the interest of achieving these goals as fully as possible within existing time and funding constraints, it was necessary to assign priorities to those portions of the model which relate to the field data against which it was to be compared.

After examining several possible alternatives, a study of solid wastes in parts of Jefferson County, Kentucy, was selected for comparison. This study,[2] directed by Professor John Heer at the University of Louisville, was conducted in such a way that residential household solid wastes were isolated and measured independent of wastes from other sources. Since the primary emphasis in the URS study was in the household waste prediction model, it was decided to concentrate on predicting the equivalent waste components.*

The following paragraphs discuss how the particular functions diagrammed in Fig. 3 were performed in developing and applying the model for the test case.

Community and Expenditure Data

Data for block a (the description of households in study area) were obtained primarily from Bureau of Census publications. The most important information included the population, the average size of the household unit,** and the general geographical location.***

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* Examination of University of Louisvilles' preliminary results seemed to indicate LRT items did not contribute significantly to the waste. For this reason and because of the problems discussed in Section 4, no attempt was made to estimate these items.

** The average household size for Jefferson County is 3.42 persons. The national average is 3.36 persons.[9] The conversion factors 3.36/3.42 was applied, where appropriate, to adjust data represented on a national basis.

*** The portion of the LIFE Study data which applied to the north central section of the United States was used in this study.

Data for block b (consumer expenditures by household) were obtained from the LIFE Study discussed previously. Tables 2 and 3 suggest the degree of detail provided in the LIFE Study. For our purposes, not all the data were of value, since a large portion pertained to expenditures on items which do not contribute significantly to household solid wastes. Considering the LIFE data as comprising a matrix, the portion drawn upon most heavily by our prototype model had the following row headings:

- Food, beverages, and tobacco
- Household supplies
- Personal care supplies
- Clothing and accessories
- Other SRT items

Some 130 consumer items were considered in detail to determine how they contribute to waste generation. The major household characteristic considered in the test case was "geographical region" (the North-Central region of the U.S. was used). Expenditure data for this region was adjusted to reflect the fact that Jefferson County tends to have somewhat larger households than the national average. It was originally intended to consider several income levels independently, but, for the reasons discussed on page 39, only the average income for all households was used.

Material Price and Composition Factors

Data for block d (the price/amount conversion factors) were generated using information such as that contained in blocks e, f, and g, but did not employ a formalized mathematical model. Rather, information concerning the market coverage and prices of various sizes and types of consumer items were manipulated by hand to obtain price-versus-amount conversion factors. Coverage and price information were obtained from various sources, including production statistics, wholesale and retail trade statistics, and communication with persons employed in the appropriate retail businesses.[8] The decision to generate the conversion factors by hand rather than by a mathematical model was made in the interests of maintaining as much flexibility as possible during this developmental stage.*

*Because of their size and complexity, the tabulations of data and results of computations are not included in this report. Copies can be made available to authorized requestors.

Block i (the description of each item's physical characteristics and material composition) was generated using information such as that contained in blocks f, g, and h. Block h, the descriptions of size and type of each item, was developed by actually dissecting several hundred common consumer items and weighing (or otherwise measuring) their respective component parts and materials.

Since the present study is concerned primarily with the development and demonstration of a prediction technique, it was decided to describe wastes in terms of the material classifications listed in Table 5.* These particular classifications (and aggregations) were selected because they allow the model's predictions to be compared with measured waste-generation data from the University of Louisville study. (This is described further in Section 7.) The result of this item-by-item analysis is a large and rather comprehensive tabulation of characteristics (block i).

Data for block l (the waste/item conversion factors) were developed entirely on the basis of personal experience, rather than from specific data sources. The purpose of including these factors is to provide a means for accounting for the fact that many items are purchased in one form, but discarded in a very different form. For example firewood is converted to ashes, fertilizer to garden cuttings, clothing to lint and rags, etc.

Extraneous Input Information

Block m (the mechanism for introducing extraneous information to supplement the model) was most valuable in accounting for the following:

- newspapers and periodicals
- mail (excluding periodicals)
- grocery sacks and other paper bags
- aluminum foil (that amount not elsewhere accounted for)

* The degree of detail with which items are described should be dictated by the use to which the waste-prediction information will be put. Thus, in a very comprehensive survey, pursuant to designing systems for waste collection, transport, treatment, and ultimate disposal, it may be necessary to describe all waste constituents in terms of their material composition as well as their physical, chemical, and biological properties. In less comprehensive studies, it is not necessary to describe wastes in such detail.

TABLE 5. MATERIAL CLASSIFICATIONS BY WHICH WASTES ARE DESCRIBED IN PROTOTYPE MODEL

Combustible materials:

- paper and cardboard
- plastics
- rubber
- textiles
- leather
- wood
- leaves and grass
- other combustibles (excluding garbage)

Food - derived garbage

Metals:

- ferrous metals
- aluminum and its alloys
- copper and its alloys
- other metals

Glass

Refractory materials (excluding glass)

- aerosol-type metal cans
- miscellaneous plastic bottles (those not elsewhere accounted for)
- textile materials

The advantage of handling the first three entries in this manner was discussed earlier. The remainder were introduced in this way primarily because they tend to enter the household in association with a great variety of consumer items. This approach, that of using production statistics for the materials themselves, will provide reliable estimates of their rate of consumption by the household, provided the materials are used somewhat uniformly by all classes of households.

In this study, the data for block o (the distribution factors to reflect household waste management practices) were developed on an intuitive basis, rather than on the basis of blocks a and p. As mentioned previously, at the present state of the art, sufficiently detailed information is not available for predicting how a household's waste management practices vary relative to measurable demographic and socio-economic factors. For the purpose of this study, however, such a deficiency appears to be of little significance. In order to yield results which could be compared with those from the University of Louisville study (which accounted for those wastes which were found in home garbage cans),the assumption was made that wastes would be distributed throughout the various disposal alternatives in a manner which the investigators assumed was typical, based on their own experience. It was assumed that virutally all disposable packaging materials, small containers, and paper goods would be placed in the garbage can.* In addition, it was assumed that the fractions of those items which could conceivably be segregated and saved for some other form of disposal (e.g., 15 percent of returnable glass bottles, 75 percent of old clothing, 50 percent of newspapers) would also be discarded via the garbage can. Thse assumptions are only approximations but must serve until more definitive information becomes available.

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* Some of these disposable materials will not be disposed of via the home garbage can. The materials associated with lunches packed in the home but eaten elsewhere are examples of this. In this study, the only materials for which the quantities discarded at home were reduced below the total quantities were wax paper, beverage cans, and "no-deposit, no-return" beverage bottles.

The prototype's output takes the form of a series of waste inventories (blocks q, q', q'', and q'''), one for each of the major alternative means by which household wastes are disposed of. The format of these inventories is the weight of materials corresponding to each of the material classifications given in Table 5.

Section 7
RESULTS OF TEST OF PROTOTYPE MODEL

As indicated in the previous section, the solid-waste generation in residential areas of Louisville was estimated to check the feasibility of the waste prediction technique.

The University of Louisville (U.L.) study involved periodically collecting the contents of refuse containers from some 144 households throughout the study area. The particular households sampled and the collection schedule employed were both carefully selected to obtain representative samples of residential solid waste. These samples were then assayed to determine both quantity and character, as expressed by a number of physical and chemical indices.

Even though our study and the U.L. study were both directed toward solid-waste generation from households in the same community, certain factors were expected to interfere with their direct comparison. For example, although the U.L. study considers the same waste items considered in the URS study, it can account for them only if the householder disposes of them via the refuse container. That is, if the householder disposed of the waste in some other fashion (e.g., by separate collection or perhaps on-site composting or burning), it was not counted. Similarly, wastes disposed of by any route other than the common refuse container (e.g., those disposed of via the sink garbage grinder, segregation for salvage, on-site incineration, etc.) would not show up in the U.L. samples. These differences between the two studies are cited primarily to indicate that each method is based upon simplifying assumptions which impose limitations, some of which complicate the task of comparing their respective results.

In many ways Jefferson County was a good test community:

- It constitutes part of an SMSA*, an area for which a rather large amount of statistical data is readily available.

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* U.S. Department of Commerce has designated Jefferson County, Kentucky, and both Clark and Floyd Counties, Indiana, as the "Louisville, Kentucky-Indiana Standard Metropolitan Statistical Area (SMSA). The principal cities included are Louisville, Kentucky, and New Albany, Indiana.

- It is neither entirely isolated geographically, nor is it submerged within a megalopolis.
- It has had a reasonably stable population growth pattern and does not, therefore, exhibit some of the difficulties of areas which have "boomed" or are declining in stature.

A primary goal of the U.L. study was to determine the relationship between a household's income and its waste generation. To accomplish this, the sample households were divided into three income brackets, and waste samples were collected and analyzed to determine the manner in which their amount and content correlated with income level.

The initial plans for this study included a similar goal. It had been intended to take advantage of the fact that our expenditure data[3] include information on the manner in which household consumption patterns vary as a function of income level. It was planned to use this information in our model to develop separate waste predictions for each of three or four income levels. However, the preliminary results of the U.L. study indicate that, while waste generation is affected by income level, the statistical correlation between the two was barely significant in the Jefferson County households considered. For this reason, it was decided not to spend the limited available time and funding on a similar effort. Rather it was decided to develop income-independent predictions.* The basic household consumption information actually selected was that for all non-farm households in the north-central quadrant of the U.S. For the purpose of drawing comparisons, the U.L. data for all income groups were averaged.

URS Results

As described previously, consumer items were identified as being either SRT or LRT. During the study the waste content of approximately 120 items was determined. These items were the most important of those listed in Table 3.** The

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* This study of expenditure pattern data has led to the conclusion that income level is perhaps the most significant single factor influencing wastes. It is recommended that further studies be directed toward determining the impact of income on waste characteristics.

** The list was pared down by eliminating LRT items (and the packages for same), items with insignificant residential solid waste content, and those for which the expenditure per household was less than $.05 per week.

amount of household waste contributed by each of the purchased items was determined for each of the constituent materials. For example, the amounts of paper, plastic, and aluminum foil attributable to the consumption of two separate items, say breakfast cereal and laundry detergent, were determined and tabulated separately. Table 6 presents these amounts in terms of pounds of waste material per household per week.

Many of the spaces in Table 6 are simply shaded grey. This designates that the amount of waste material so identified is "not significant" relative to the total amount of solid waste generated. The asterisks appearing on Table 6 signify values which we feel to be significant waste constituents, but for which we have not been able to obtain sufficiently complete information to allow prediction. For example, "food-derived garbage" is a category which is surely significant. However, we are presently not able to predict with accuracy the rate at which this material is produced.*

Block m in the model was described earlier as providing a means for incorporating generation data for waste components whose amounts are not closely related to any particular consumer expenditure rate. The final row of entries in Table 6 consist of totals calculated for "block m" wastes, such as mail, leaves, grass, garden cuttings, and miscellaneous wastes.**

University of Louisville Study Results

Because each of the households in the U.L. study were sampled several times during their study period, the observed waste generation data were expressed in terms of a statistical distribution. These distributions are given in tabular form in Table 7 and graphically in Fig. 6 by means of a narrow band; the ends

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* It may be that this particular category of waste is best estimated on the basis of direct measurements.

** Based on U.S. Post Office statistics[6] it was estimated that some 7.1 pounds per day of paper and cardboard enter the typical Jefferson County household via the mails. On the basis of preliminary figures obtained from BSWM staff, it is estimated that some 1.7 pounds per household per week of yard wastes and 1.1 pounds per household per week of waste wood from various sources are to be expected. Circulation information and newsprint usage estimates were provided by the publisher of Louisville's principal newspapers.

TABLE 6. PREDICTION OF WASTE GENERATION RATES BY MATERIAL AND ORIGIN

CATEGORIES OF WASTE MATERIALS

CONSUMER ITEMS:	paper and cardboard	plastics	rubber	textiles	leather	wood	leaves and grass	other combustibles	food-derived garbage	ferrous metals	aluminum and its alloys	copper and its alloys	other metals	glass	refractory materials
food, beverages, and tobacco	1.49	.15							*	2.04	.12			3.30	
household supplies	.62	.05	*	*						.13	*			*	
personal care supplies	.42	*	NOT A SIGNIFICANT AMOUNT OF WASTE							.04	*			.93	
clothing and accessories		*	*	1.00	*										
wastes from other sources (block m)	16.33	.11		.46		1.10	1.70			.15	.06				
TOTAL	18.86	.31		1.46		1.10	1.70			2.36	.18			4.23	

23.43 | 0 | 2.54 | 4.23 | 0 → 30.20

* Present data is not sufficiently complete to warrant tabulation.

TABLE 7. COMPARISON OF WASTE GENERATION RATES
(lbs/household/wk)

	MEASURED BY UNIV. OF LOUISVILLE STUDY			ESTIMATED BY URS PROTOTYPE MODEL
	low	medium	high	
paper	24.9	29.7	37.8	23.43
garbage	4.8	9.9	12.6	not estimated
glass	3.8	5.3	6.7	2.54
metal	3.9	4.7	6.0	4.23
minerals	0	0.7	3.1	not estimated

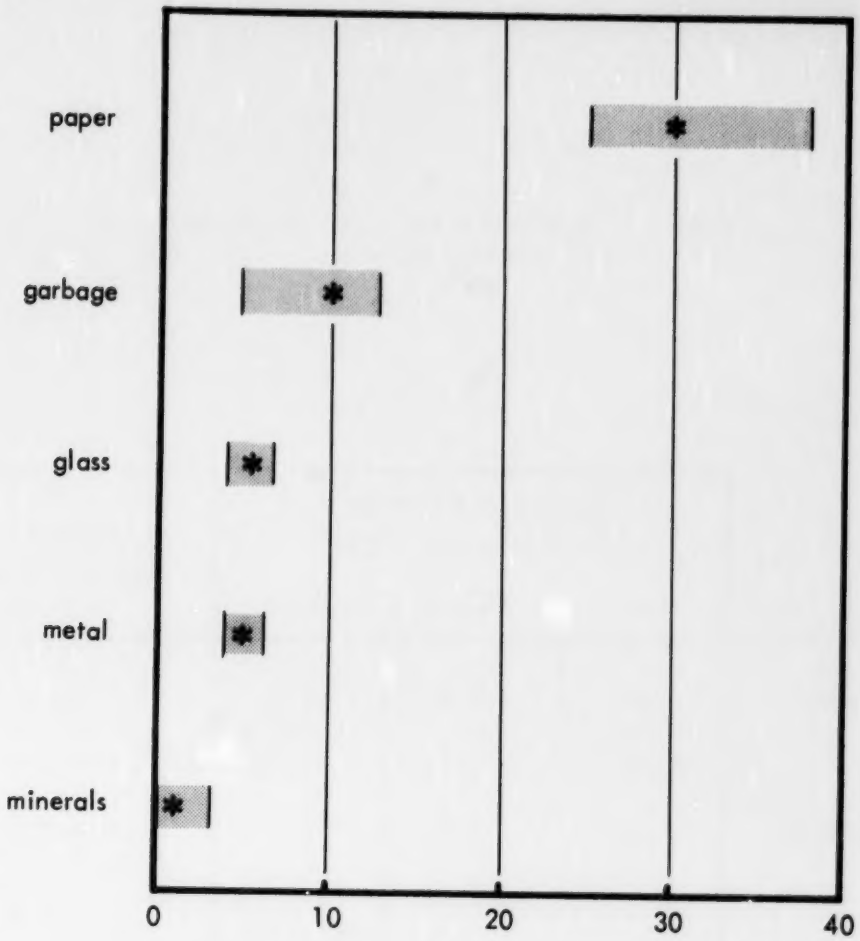


Fig. 6. Solid Waste Generation Rates Observed by University of Louisville Sampling Study

of which represent the highest and lowest rates measured, the asterisk denoting the calculated mean generation rate. The values given are expressed in "lbs of waste/household/week" rather than the "percent by weight" form used in the U.L. report.

The U.L. results also differ in format from ours. They segregate waste materials into the five categories listed in Fig. 6, whereas this study employs fifteen material categories. Table 8 has been included to indicate the relationship between the two systems. It should be pointed out that the lack of conflict between the two systems stems from the fact that we were aware of their format and designed ours to be merely an expansion of it. The expanded format is, of course, quite desirable in that it provides the degree of flexibility necessary to make the data applicable to a wide range of uses.

Comparison of Studies

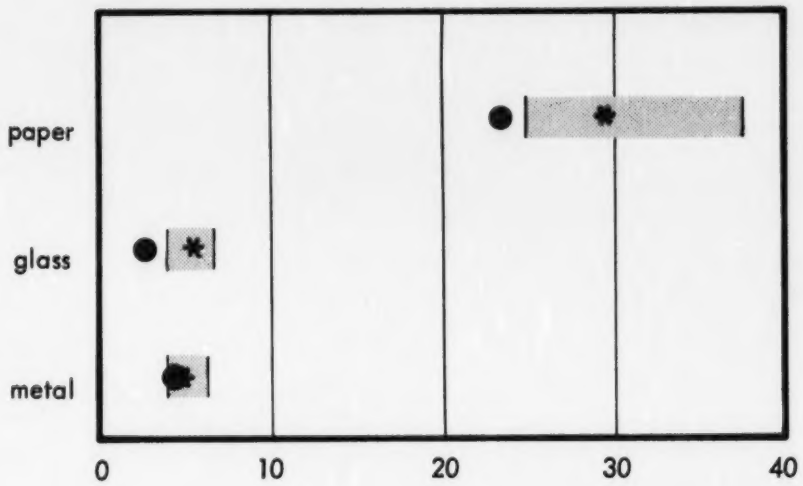
In the lower portion of Table 6, predicted waste generation rates have been summed into five categories, which correspond to those in the U.L. report. These summations have been plotted as bold dots in Fig. 7 (and are listed in Table 7) to allow comparison with the U.L. results. Note that each of the predicted values is smaller than the corresponding value measured by U.L. This would be expected, since none of the predictions are complete to date (i.e., for each, there are items which have not yet been fully accounted for).

We believe that the performance of the prototype computation is quite satisfactory. The discrepancies between the URS study and the sampling study are well within the expectation for this preliminary trial of a novel technique. Furthermore, the discrepancies are explained by the fact that the present model is based upon only a minimum amount of information. It was stated previously that the prototype model used for the comparison study considers only SRT items and packaging materials and excludes LRT items. It is believed that, given the opportunity to include these and other excluded items and to refine various other preliminary estimates and approximations, the waste generation rates predicted by the model would progressively approach the actual average rates.*

* It should be recognized that the actual average rates are not necessarily equal to those measured since measurement techniques usually suffer from sampling and other errors.

Table 8 - COMPARISON OF OUTPUT DATA FORMATS

UNIVERSITY OF LOUISVILLE WASTE CATAGORIES	URS PROTOTYPE WASTE CATAGORIES
paper	paper and cardboard
	plastics
	rubber
	textiles
	leather
	wood
	leaves and grass
	other combustibles (excluding garbage)
garbage	food - derived garbage
metal	ferrous metals
	aluminum and its alloys
	copper and its alloys
	other metals
glass	glass
minerals	refractory materials (excluding glass)



HOUSEHOLD SOLID WASTE GENERATION RATES

(lbs/household/week)

● Value predicted by URS prototype model

▭ Range of all measured values

* Mean

NOTE: URS results are superimposed over University of Louisville results.

Fig. 7. Solid Waste Generation Rates Predicted by Using URS Prototype

Section 8
CONCLUSIONS AND RECOMMENDATIONS

The solid-waste prediction method investigated in this project is technically feasible and appears to offer a unique and effective means of estimating waste quantities and characteristics. In addition, it provides a framework for the prediction of future wastes. Figure 8 indicates the relation of the progress to date (Phase I) to the overall requirements of the program and suggests that subsequent work be undertaken in two phases. Phase II, the next logical step, would be devoted to completing the capability to predict the solid wastes from residential, commercial, and institutional activities in the community. These wastes make up a large fraction of the solid wastes arriving at disposal sites and are very susceptible to changes (as a result of changing technology) that affect waste handling and disposal operations. Also, pertinent input data are generally available, concerning these wastes. For these reasons, it appears desirable to give priority to these aspects of the work. However, in Phase II, the problems of predicting solid wastes from industrial, agricultural, and other sources would also be investigated; at least through the stage of a test of the approaches. The major and final development of prediction methods for wastes from these sources would constitute the third phase of the work. The reasons for relegating these to Phase III are:

- Current work (being done by other contractors) as well as planned studies concerning industrial and agricultural wastes should be used as a basis for the proposed prediction methods. The results will not be available to an appreciable extent during the Phase II period.
- The requirements for a computerized solid-waste estimation procedure for industrial, agricultural and possibly other wastes have not been defined and/or delineated.

Both of these deficiencies would be resolved by the preliminary studies in Phase II, thereby permitting decisions to be made concerning the need for Phase III and specific approaches to be taken therein.

WASTE TYPES	DEVELOPMENT STAGES: conceptual design	preliminary data collection	manual test	final design program for computer	complete data collection	computer test
residential, SRT*	Phase I (completed)					
residential, LRT						
residential, future						
commercial				Phase II		
institutional						
industrial						
agricultural					Phase III	
other						

* SRT - short residence time items
LRT - long residence time items

Fig. 8. Prediction Method Status and Proposed Work

The major tasks that should be undertaken in Phase II are:

1. Complete the development of the residential household waste generation model, including those aspects related to LRT items and the prediction of future wastes.

2. Adapt the model to handle the wastes generated by commercial, institutional, and other activities that are found to be major contributors.

3. Perform preliminary model design and conduct a feasibility study for prediction of industrial, agricultural, and other wastes.

4. Establish computation specifications; reevaluate preliminary residential model; relate desired model specifications to computer capacity and operating cost; firm up computer model specifications; establish input, output, and function formats.

5. Develop computer program; prepare flow diagrams and design overall program; prepare and debug programs; verify running times.

6. Expand standard data banks; collect, evaluate, and collate as many standard activity and commodity descriptions as are pertinent to the test area (see task 7); put data in computer format.

7. Select test area; develop test area data; collect, evaluate, and compile input commodity and activities inventories and schedules for area, including population, land use, and other changes; put data in computer format.

8. Run waste prediction for test area; compute several pertinent predictions for a range of conditions.

9. Evaluate results; compare predictions with independent estimates or surveys; prepare report.

Section 9
REFERENCES

NOTE: Perhaps one of the more valuable results of performing the present study was the collection and evaluation of a large body of statistical information concerning community inputs and activities. More specifically, this information consists of industrial and agricultural production rates, commercial sales activity, personal consumption patterns, and the like. While the amount and detail of information is not readily describable, some feeling may be obtained by considering that over two hundred documents constitute the basic bibliography (all of these contain information which has direct bearing on predicting waste generation). For simplicity, however, only those sources of information which precisely document the text of this report have been cited herein:

Ref. 1 Office of Statistical Standards. Standard industrial classification manual. Bureau of the Budget, 1967.

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Ref. 6 Heer, John E. Solid waste study and planning grant for Jefferson County (progress report 1/66 to 5/67). Univ. of Louisville Institute of Industrial Research, 1967.

Ref. 7 Bureau of Census, U.S. Dept. of Commerce. "Special Report on household ownership and purchases of automobiles and selected household durables." In Consumer Buying Indicators, No. 18, Aug. 1967.

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Ref. 10 Correspondence with Bremer Ehrler, Postmaster, Louisville, Ky. (Oct. 1968) and with R. R. Germain, Asst. to Regional Director, San Francisco Regional Office, U.S. Post Office Dept. (July 1968).

Ref. 11 Correspondence with L. A. Kern, Traffic Manager for Louisville Times and Courier-Journal (July 1968).